

From Biomass to Advanced BioFuels

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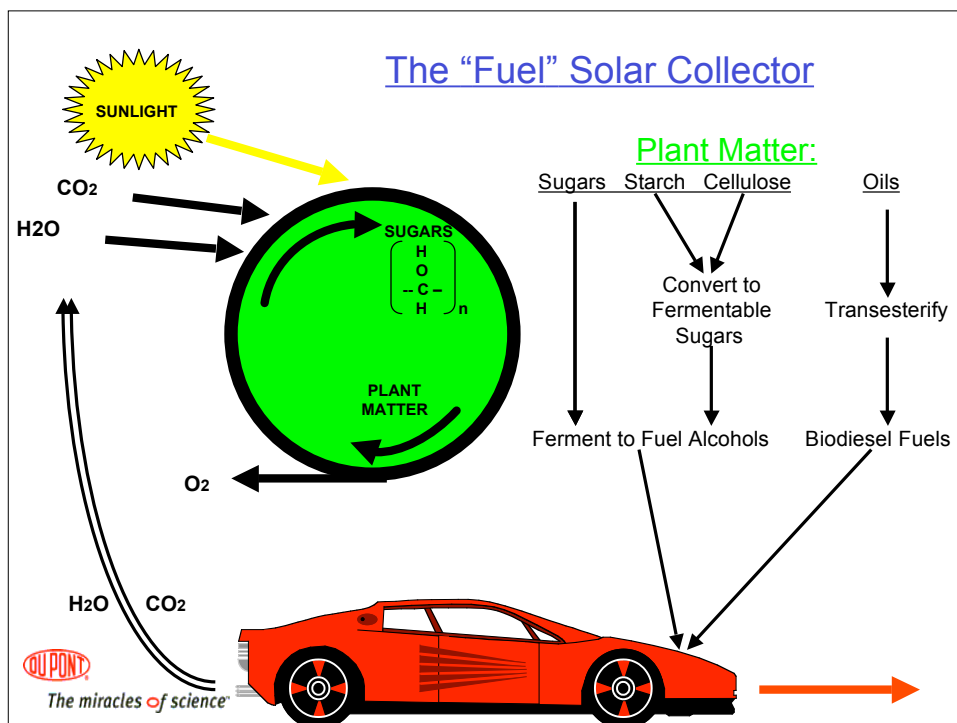
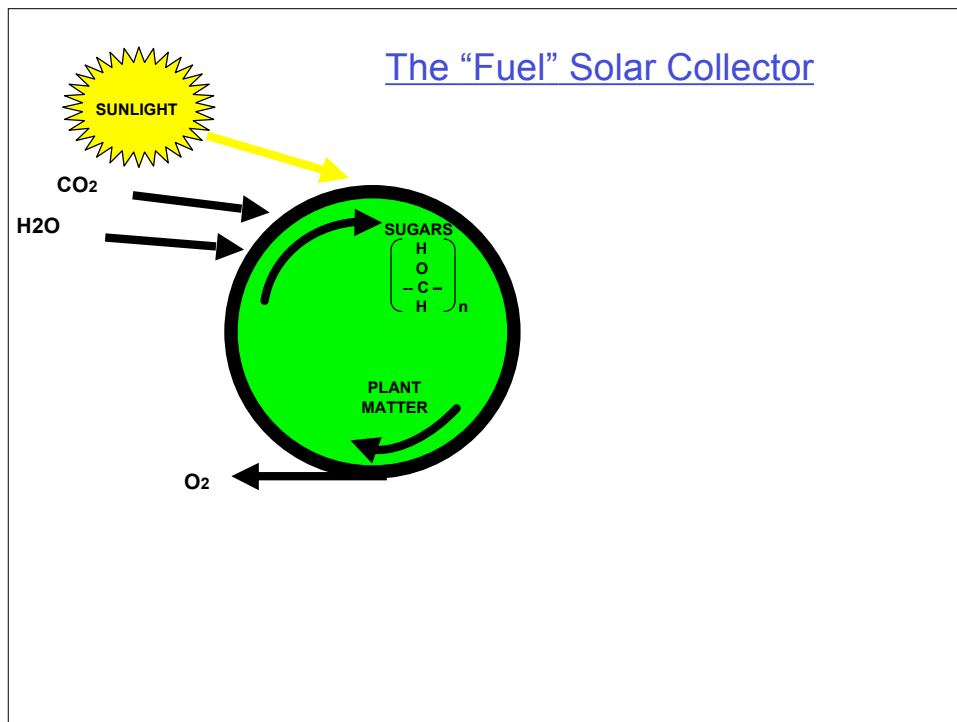
Outline

- The "Fuels" Solar Collector
- Change Drivers
 - Global
 - National
 - Business
- Change Enablers
 - Technology
 - Alternative Feedstocks
 - Alternative Fuel Products
- Biofuels: Where is DuPont Today?
- Action Item

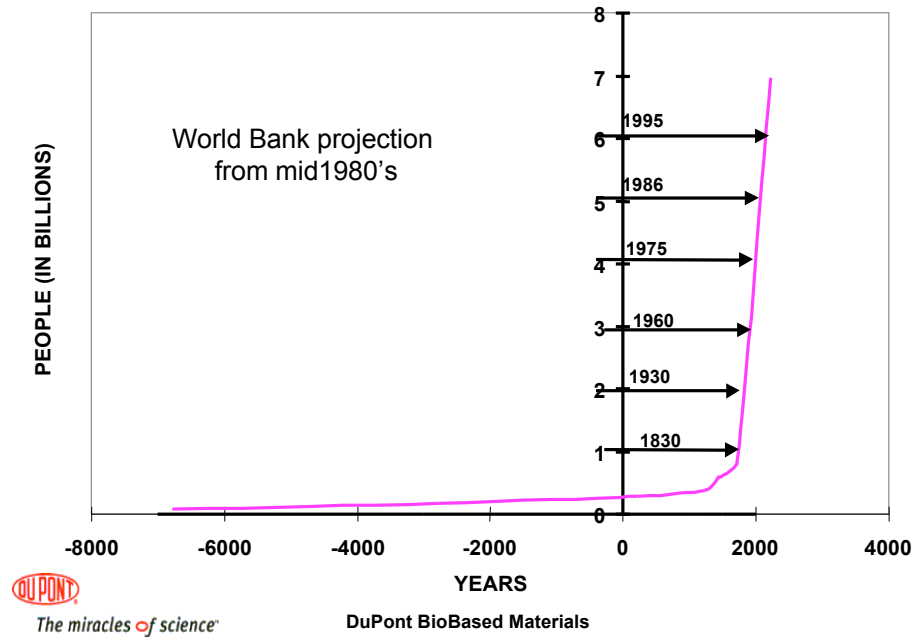


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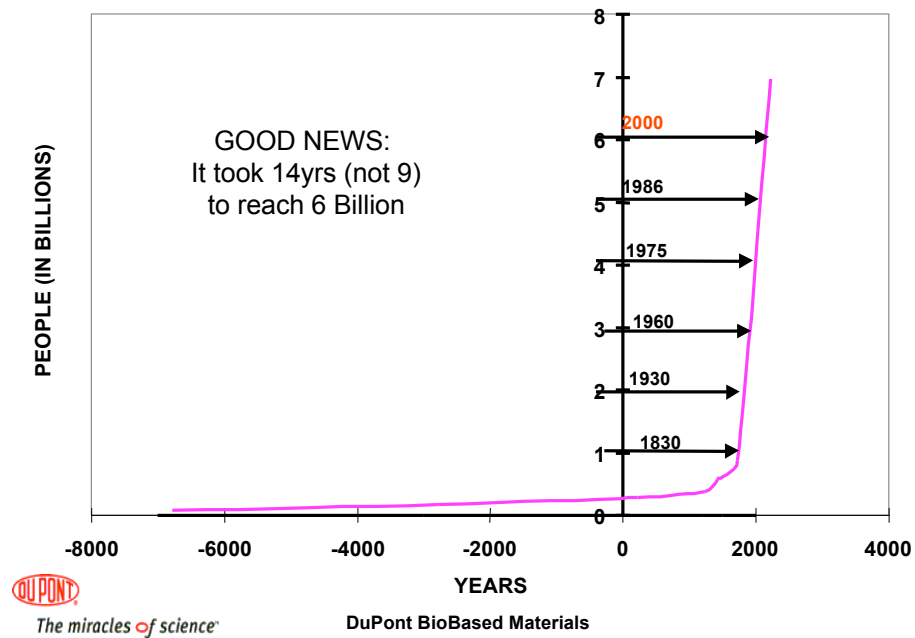
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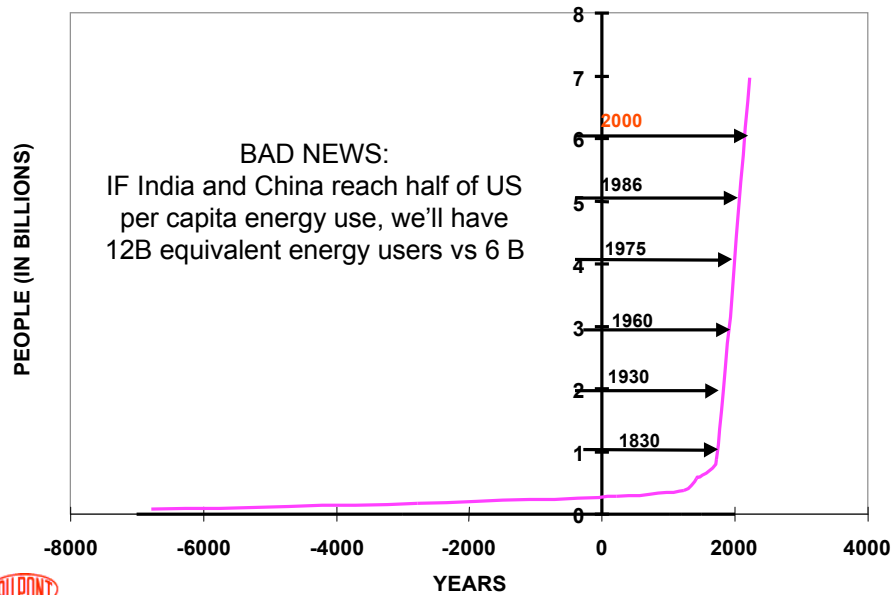
Global Change Driver: Population Growth



Global Change Driver: Population Growth



Global Change Driver: Development Growth



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Global Change Driver: Climate Change

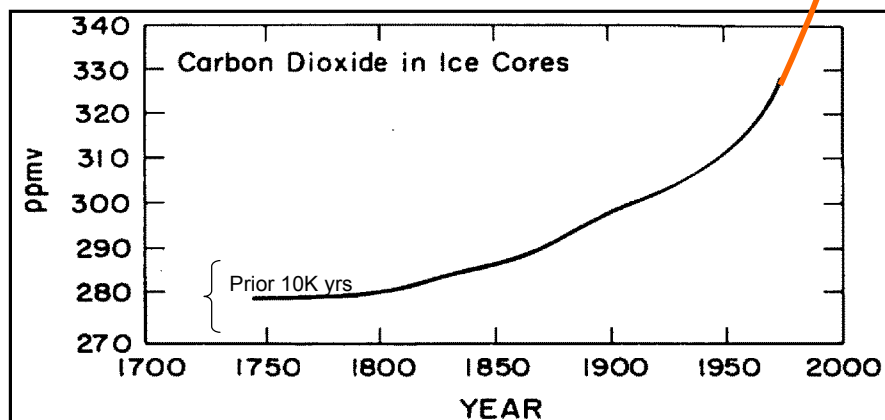


FIGURE 10. The concentration of carbon dioxide found in air trapped at different depths in polar ice. The concentration is in parts per million by volume.



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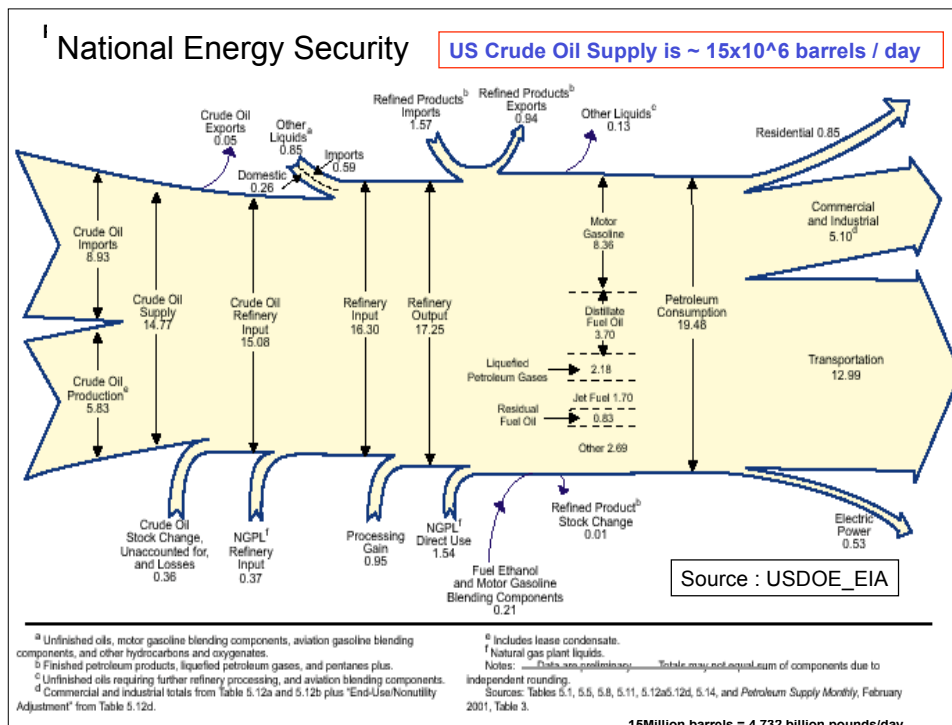
National Change Drivers

- Energy Security
 - We spend \$500million / day on imported oil
 - We spend \$300million / day in Iraq
- Preservation of American Farming
- Voter Unrest over Gasoline Prices
- Preservation of the IC powered Cars and Trucks



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Business Change Drivers

- MTBE phase-out / replacement with ethanol
- Crude pricing: high and highly variable
- Federal Energy Policy Act of 2005
 - 7.5 billion gallons of renewable fuels by 2012



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Change Enablers

- CO₂ and Solar Energy are “free”, H₂O almost
- Technology to “collect” becoming ever more efficient

For Renewable Fuels and Materials

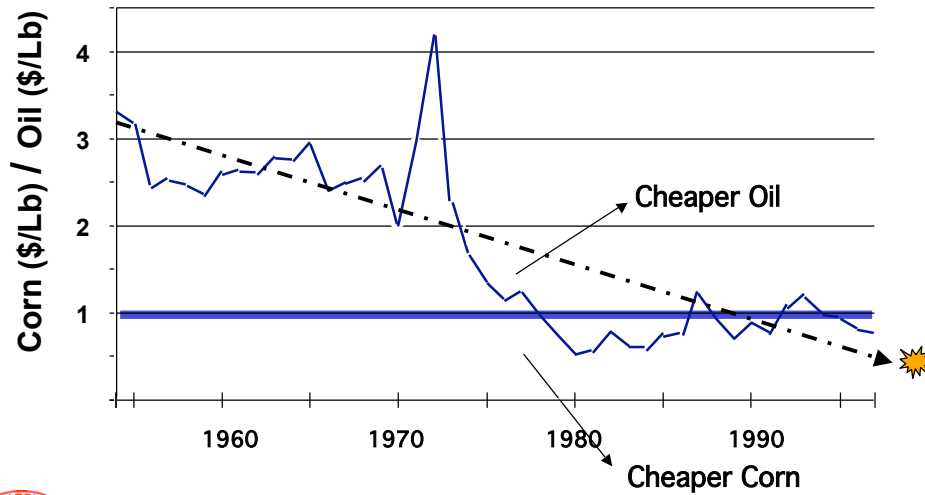
- Ever more efficient agriculture provides raw materials
 - ~1.5% corn yield improvement year over year
 - Reduced inputs of fuel, fertilizer and energy
- Technologies are ever better
 - Biotechnology for better crops and better microbes for fermentation
 - Engineering for better processes and production facilities



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Costs of Corn & Oil are Comparable



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Generic Bioprocesses

- Produce & harvest complex raw material
- Convert complex raw materials to simple sugars
 - Thermo-mechanical stage
 - Chemo-enzymatic stage
- Convert sugars to product target
 - Fermentation stage – Microbes for efficient production
 - Yield of Product from sugar in wt %, controls cost of manufacture
 - Rate of Product per liter per hour, controls fermentation invest.
 - Titer of Product grams per liter, controls separation invest.
 - Separation stage
 - Co-product utilization
 - Waste utilization
 - Final product purification
- Product enters usage
 - Easiest entre' into existing infrastructure



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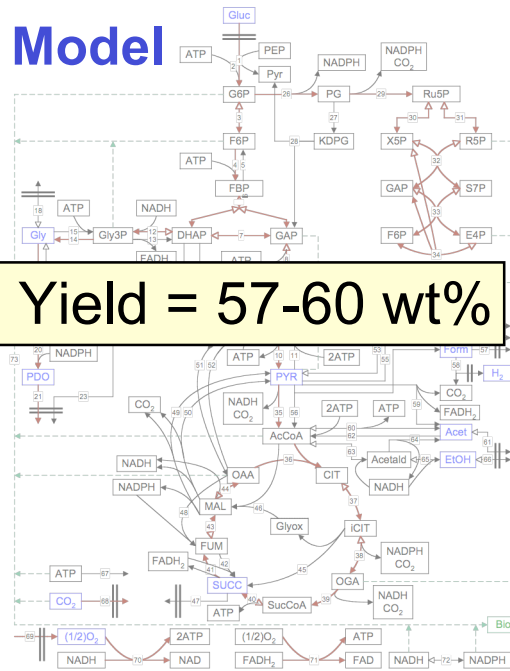
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Product Flux Model

- Glucose to 3G
- 73 reactions
- 43 species
- 14 measurements
 - Glucose

Theoretical Yield = 57-60 wt%

- Ethanol
- Lactic acid
- Formic acid
- Acetic Acid
- Pyruvic Acid
- Succinic Acid
- H₂
- CO₂
- O₂
- Biomass

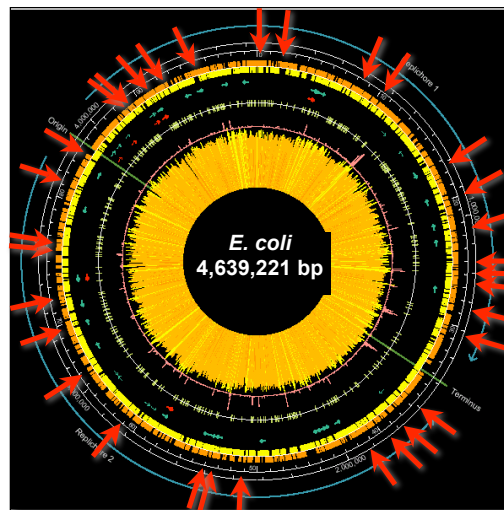


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Host Modifications

- Glucose transport
- Glycerol metabolism
- Glycolysis
- Entner-Doudoroff
- Pentose phosphate
- TCA cycle
- Respiration
- Amino acid biosynthesis
- Anapleurotic reactions
- Global regulators



Building the Cell Factory



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DuPont venture set to bolster 'green' products

Corn-based offerings to be key in some plastics

By LULADEY B. TADESSE, The News Journal



based product Monday from its plant in Loudon, Tenn. ed Kingdom-based Tate & Lyle was set up in 2004 to introduce more d propanediol, a key ingredient in specialty plastics like Sorona. plastics. The corn sugar-based propanediol will consist of 40 percent and apparel, the corn sugar propanediol will be used in a variety of

"I don't think there is going to be any major change in price today," he in the price of petrochemicals."



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Biofuels: Where is World Today?

- Biodiesel - Key focus in EU as it is "diesel centric"
- Ethanol in "gasoline centric" locations
 - Brazil and Australia > Cane sucrose to ethanol
 - US (2012 target is 7.5 Billion Gals / year from corn grain)
 - Wet Milled Corn to 1.35 billion gal (~ 15 plants, half owned by ADM)
 - Operating Dry Milled Corn > 3.7 B Gal from 80 plants
 - Average is ~40 million gal per year
 - 8 of these are under 12 million gal per year
 - Dry Mills Being Built ~ 52 plants to give next 3.5 B gal
 - **New technologies for cellulosic biomass to ethanol**
- Butanol
 - DuPont / BP JV is big player, others are dabbling, "buzz" building



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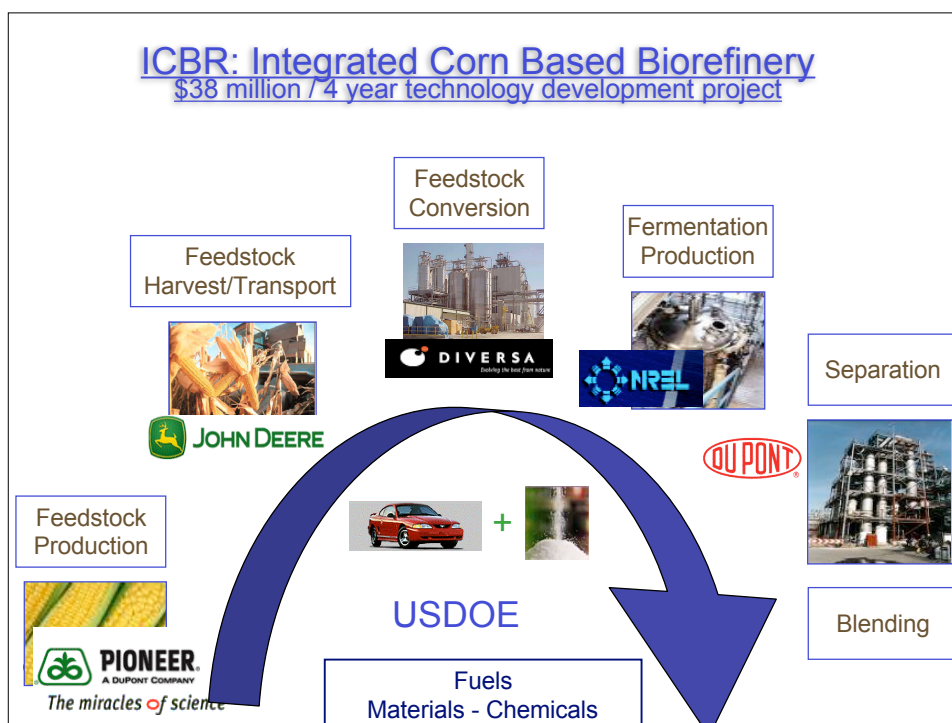


A truck load of corn stover



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Biofuels: Where is DuPont Today?

- In Ethanol
 - Cellulosics to ethanol: DuPont + USDOE > ICBR Project
 - New project: ICBR technology in with Broin building ~\$200m plant
- In Butanol
 - Joint effort with BP announced 6/20/2006, in 3rd year
 - Project #1 – new process technology for low cost biobutanol
 - Project #2 – marketing biobutanol in UK in 2007
- Discussions of opportunities with / within Delaware
 - Delaware is developing “political will”
 - Has strong biotech and engineering base within Universities



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Why an alternative to Ethanol?

<u>Characteristic</u>	<u>Ethanol</u>	<u>Butanol</u>
Energy content	Fair	Good
Ease of Use		
RVP	Poor	Good
Blending	Poor	Good
Mileage	Less	Good
H2O absorption	High	Low
Pipelining	No Go	Easy
Engines	Modified	As Is
Cost	Slightly lower	Slightly higher



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Key Points for Potential Joint Effort

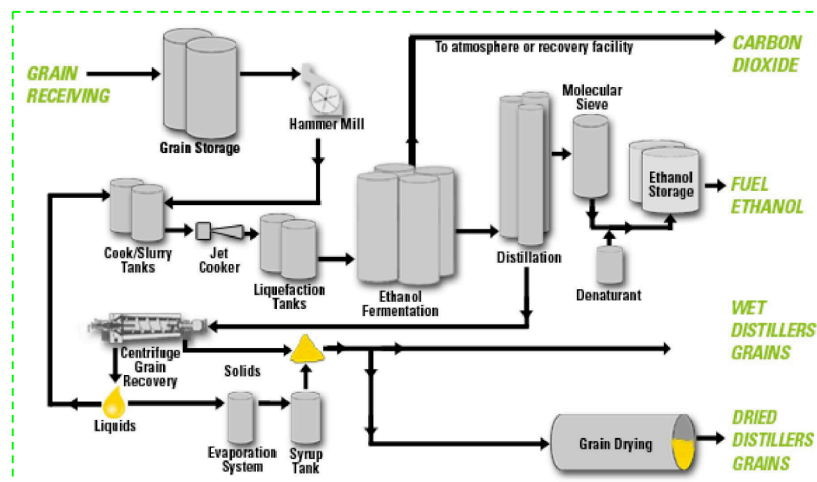
- Key assumption: DuPont controls all IP in the end
- Key Questions:
 - What (new?) entity is in control?
 - Organism: How does biology get done?
 - Process: How does engineering get done?
 - Plant demonstration: How, where...?
- There are a small handful of possible project targets
- Example hypothesis: Build program around purchased, small scale, dry mill relocated to Delaware, development effort staffed by combined technical professionals from DuPont and University, located on brownfield site providing all utilities and services.



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Dry Mill



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Remaking Dry Mill into Ethanol / BioButanol Plants Develop and Demonstrate New Delaware Based Technology and Plant

2) Biotech Team, DuPont & Universities, engineer production Microbe

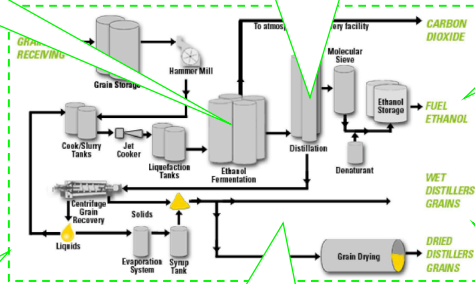
3) Chem Engr team, DuPont & Universities, re-engineer production process & plant

4) First produce Ethanol, then convert to ethanol / butanol production

1) Establish small Dry Mill Ethanol plant at site in DE, work to learn

6) New Knowledge & Technology from DD+DE licensed to US

5) Produce high quality animal feeds for DE AG industry



Potential Impact: 100 plants converted to "New Tech" in 15 years

Proposed Action Item

Establish a study group,
composed of DuPont/UD/DBI personnel,
to outline a program proposal including
boundary conditions,
responsibilities and
budgets,
to develop the science and technology for the
conversion of biomass to
advanced renewable fuels,
such as ethanol and butanol.



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